Learning Measurement with Interactive Stations

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This paper shares seven interactive stations teaching measurement concepts and skills: Measuring Weights; Comparing Volumes of Cylinders; Comparing Volumes of Various Bottles; Measuring Areas of Irregular Shapes; Measuring Perimeters of Irregular Shapes; Comparing Volumes of Prisms and Pyramids; and Comparing Volume of Cone to Sphere. These stations engage students in measuring real life objects, using different measurement units and tools, and working with embedded problems. Authors describe the objective, main mathematical concepts, and possible extension ideas for each station.

Introduction

The study of measurement is central in PreK – 12 mathematics education, because it is practical and pervasive in everyday life (NCTM, 2000). The measurement skills that are used in daily life involve measuring length, angles, weight, capacity, time, temperature, and so on. The Common Core State Standards for Mathematics (NCTM, 2010) also acknowledge the close relationship between real world context and measurement concepts: "In real world problems, the answers are usually not numbers but quantities: numbers with units, which involve measurement. In students' work in measurement up through Grade 8, they primarily measure commonly used attributes such as length, area, and volume" (p. 58).

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In addition to applying measurement skills in daily life, measurement concepts are also connected with other mathematics content strands and with other subjects. The study of measurement provides an opportunity for learning about other areas of mathematics, such as number operations, geometric ideas, statistical concepts, and notions of function: the metric system based on the base-ten concepts enriches students' understanding of place value; applying estimation strategies; applying the concepts of similarity and scaling; collecting and analyzing data; and reasoning and generalizing techniques to produce formulas.

State, national, and international assessments of mathematical knowledge and achievement indicate measurement as one of the most difficult mathematical strands (Preston & Thompson, 2004). Middle level teachers report that measurement is an important strand, but it is the content strand with which students have the most difficulty. This includes measuring the circumference and height of a cylinder, converting measurement units between metric and customary units, applying units, and solving problems involving measurement (Preston & Thompson, 2004). Why then is measurement so difficult and what should be done to help students?

An effective measurement lesson allows students to learn to measure actual objects using a variety of tools. The best way to teach measurement concepts is to offer students the opportunity to measure in the real world, choose appropriate tools, select an appropriate measurement unit, and check the reasonableness of their results. In the mathematics classroom, however, students are rarely given opportunities to practice measurement skills. Measurement experiences embedded in good problems help students enhance meaningful learning (Martini, 2004).

To involve students in measuring real life objects, using different measurement units and tools, we have developed seven measurement learning stations. The purpose of these stations is to engage students in meaningful mathematics and to use manipulatives and easily accessible objects that make mathematics a hands-on, interactive, and real-life experience. In the following section, we describe the objective, main mathematical concepts, and possible extension ideas for each station. We also share our suggestions based on our experience and observations. Pictures, directions, and worksheets for each of the seven stations are given as part of the station description.

Measurement Stations

Before starting a measurement station activity, we recommend spending a full class period discussing the purpose, expectations, procedures, and evaluation process of each station. Also, it is important to let students know the value of group discussion and collaborative learning during each station activity. Then students are divided into groups of three or four for a station activity. Students are allowed to spend 10-15 minutes at each station before moving to the next station. After a small-group station activity, students return to their seats to complete the answers to questions and to participate in a discussion lasting a full class period. During the class discussion time, students' answers are listed on the board, and students are asked to elaborate on and clarify their statements. The time frame required for completion of all seven stations as well as the preparatory discussion and summative discussion is approximately four 45-minute class periods.

Table 1 summarizes how each station meets the *Principles and Standards for School Mathematics* (NCTM) Grade 6 – 8 Expectations.

After a small-group station activity, students return to their seats to complete the answers to questions and to participate in a discussion lasting a full class period

Table 1 Connections between Measurement Stations and *NCTM* (2000) *Standards*

Grades 6–8 Expectations In grades 6–8 all students should	**Stations**						
	A	B	C	D	E	F	G
understand both metric and customary systems of measurement	X	X	X			X	X
understand relationships among units and convert from one unit to another within the same system	X	X	X	X	X	X	X
understand, select, and use units of appropriate size and type to measure angles, perimeter, area, surface area, and volume		X	X	X	X	X	X
use common benchmarks to select appropriate methods for estimating measurements	X	X	X	X	X	X	X
select and apply techniques and tools to accurately find length, area, volume, and angle measures to appropriate levels of precision		X	X	X	X	X	X
develop and use formulas to determine the circumference of circles and the area of triangles, parallelograms, trapezoids and circles, and to develop strategies to find the area of more-complex shapes		X		X	X		X
develop strategies to determine the surface area and volume of selected prisms, pyramids, and cylinders		X				X	X
solve problems involving scale factors, using ratio and proportion						X	X
solve simple problems involving rates and derived measurements for such attributes as velocity and density	X						

Station A: Measuring Weights

Objectives

The objective of Station A is for students to predict the weight of various objects before actually measuring them with a balance scale and standard weights. Students are first asked to estimate the weight of the objects provided by holding each one in their hands, and compare their weights. After estimating the weights, to weigh each object, students use a balance scale and standard weights, either in metric (grams) or customary (ounces) units of weight. Finally, students reflect on how close their prediction of the actual weights was, and what may account for the errors in those predictions.

Students are first asked to estimate the weight of the objects provided by holding each one in their hands, and compare their weights.

Mathematical Concepts

The mathematical concepts involved in Station A are: estimation, weight, weight comparison, use of a scale and standard weights, and how the shape of an object affects weight distribution, density, and mass.

Fig 1 Station A materials

Extensions

This station can easily be adapted to include standard units of measurement. A simple spring scale is effective in estimating and weighing objects such as an orange, textbook, shoe, student folder, etc.

Notes

Students and adults alike will find that they are generally weak at estimating the weight of an object. This station will challenge their perceptions of how heavy an object feels in comparison to its actual weight. Be prepared to have a discussion about weight dispersion based on the object's shape. A nice comparison to use is the style of a snow shoe and why it is so effective in not breaking through the snow or ice. A brief session on how to set the balance scale to level and use the scale is sometimes necessary for students to be efficient at this station.

Station B: Comparing Volumes of Cylinders

Objectives

The objective of Station B is for students to compare the volume of two cylinders that have equal wall area. Students are asked to predict and compare the volume of each cylinder. They are expected to explain predictions in writing. After that, students measure, using rice, and compare the actual volumes of the two cylinders.

Mathematical Concepts

The mathematical concepts involved in Station B are: estimation, volume, circumference, and the effect that changing one dimension compared to changing two dimensions has on the volume of an object.

Extensions

Use the formula for the volume of a cylinder to calculate the volume of each cylinder. The formula for volume can be provided.

Notes

This station is a favorite among students and has a lasting impact on their learning. Most students and adults will predict that, because the wall area is the same for both cylinders, the volumes will be equal. Students remember the "surprising" outcome long after the measurement activity has ended. It is not necessary to have students measure and calculate volume using the formula. The learning that needs to take place at this station comes from simply filling one cylinder and then using that quantity to try to fill the other. The real discussion should be as to why the shorter and wider cylinder has the larger volume.

Fig 2 Station B materials

Station C: Comparing Volumes of Various Bottles

Objectives

The objective of Station C is for students to predict, measure, and compare the volumes of various bottles. Students are provided labeled glass bottles and asked to predict their volumes and then, using water and graduated cylinders, to determine the actual volume of each bottle.

Mathematical Concepts

The mathematical concepts for Station C are: estimation, volume, reading a graduated cylinder, and understanding the effect that the shape of a bottle has on its volume.

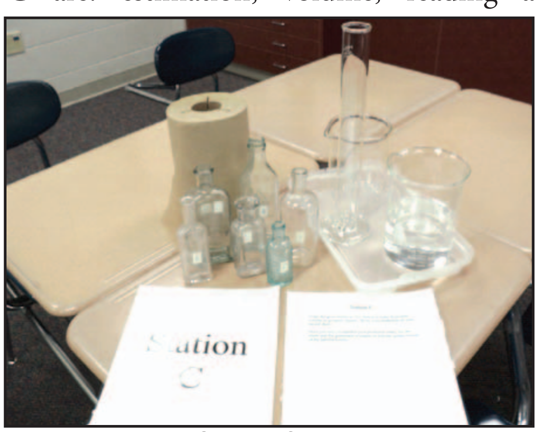

Fig 3 Station C materials

Extensions

A nice follow-up discussion to use relates to the packaging of products on our grocery shelves. Ask students to pay attention to the shapes of package or perhaps bring in differently shaped packages of the same product. Hold a discussion about which package provides the better deal for the consumer and which provides more profit for the company, and why.

Notes

While this can be a messy station, do not let that deter you from trying it. This station helps students reinforce concepts learned in Station B and is fun for the students. It also provides a link to the science classroom because of the use of the graduated cylinders. Students are often surprised to see that they are using the same tools in math as in science. Have plenty of paper towels on hand and understand that only water is spilling and water will dry. If glass bottles are used, do caution the students to be careful to avoid breaking the glass.

Stations D and E: Measuring Perimeters and Areas of Irregular Shapes

Stations D and E can use the same figures to measure area and perimeter.

Objectives

The objective of Station D is for students to predict and compare the areas of various irregular shapes. Students are asked to order the figures according to area from least to greatest and to use a transparency grid to check their predictions. The objective of Station E is to compare the perimeter of various irregular shapes. Students are asked to order the figures according to perimeter from least to greatest and then use a string to check their predictions.

Students are asked to order the figures according to area from least to greatest and to use a transparency grid to check their predictions.

Mathematical Concepts

The mathematical concepts for Stations D and E are: estimation, area, perimeter, and irregular shapes.

Extensions

Hold up your hand, fingers closed, with the palm facing the students. Then show your hand to them with fingers apart. Ask them to discuss which presentation of the hand has the greater perimeter and which has the greater area. This is a quick way to assess if the students have understood that there is no relationship between area and perimeter.

Notes

Stations D and E are the most time consuming stations. To speed the process along, monitor each station to ensure that every student in the group is actively involved. These stations require students to abandon traditional formulas for finding area and perimeter. The benefits that transpire are a clearer understanding of the characteristics of perimeter and area as well as their differences. Prior to completing this station, most students will define area as "length times width" but often do not understand the concept of area. Upon completion of this station, students are more likely to discuss area as "the amount or part of a surface that is being covered."

Students are expected to compare the cube to the pyramid using the following questions: How do their bases compare? How do their heights compare? How do their volumes compare?

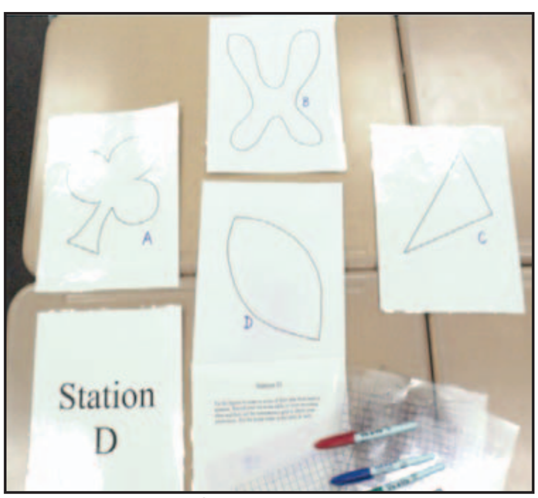

Fig 4 Station D materials

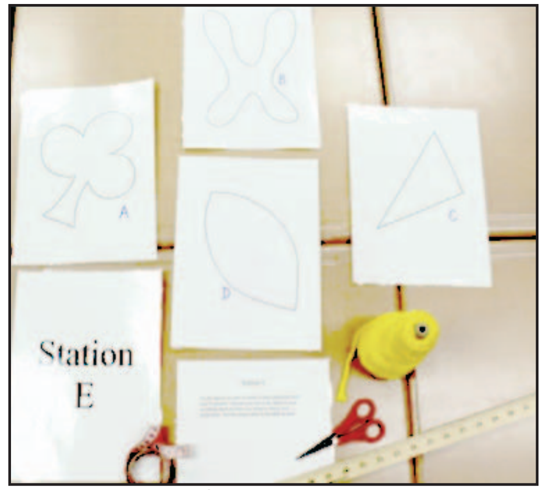

Fig 5 Station E materials

Station F: Comparing Volumes of Prisms and Pyramids

Objectives

The objective of Station F is for students to compare the volumes of a prism and a pyramid with congruent bases: a cube and a square pyramid (or a rectangular prism and a rectangular pyramid), a cylinder and a cone, and a triangular prism and a triangular pyramid.

Students are expected to compare the cube to the pyramid using the following questions: How do their bases compare? How do their heights compare? How do their volumes compare? Students are to also predict how many times larger the

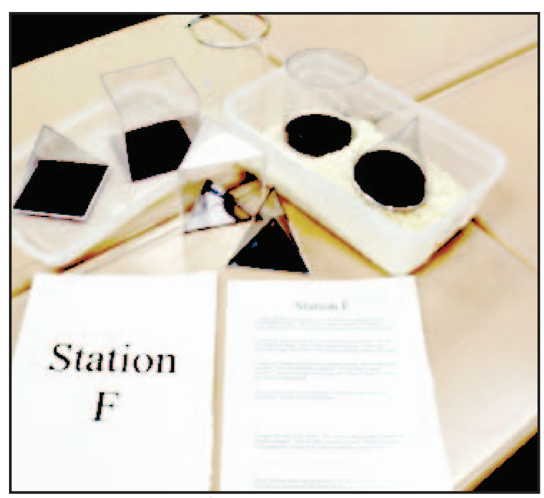

Fig 6 Station F materials

volume of the cube is than the volume of the pyramid. After that, students are asked to make predictions and use water or rice to test their predictions. Once students have completed their work with cube and pyramid, they are expected to repeat the same steps with cylinder and cone and then triangular prism and triangular pyramid.

Mathematical Concepts

The mathematical concepts for Station F are: estimation, volume of prism, volume of pyramid, bases, height, and discovery of formulas to determine volumes and surface areas of pyramids, prisms, and cones.

Notes

Rice, sand or water may be used at this station. Rice is usually the least messy but, due to the size of the grains, will yield the least accurate measurements. Make sure that the solids being used are of appropriate size. If the solids used are too small, the three-to-one relationship may not be easily noticed. Small pieces usually show a 2 1/2-to-one relationship because of the thickness of the plastic. The figures shown in the pictures have a width of 4 inches.

Station G: Comparing Volumes of Cone to Sphere

Objectives

The objective of Station G is for students to compare the volume of a cone to that of a sphere when they have the same diameter. Students are asked to compare the cone to the sphere using the following questions: How do their radii compare? How do the height of the cone and the diameter of the sphere compare? How do their volumes compare? They are expected to predict how many times larger the volume of the sphere is than the volume of the cone. Once students have made their predictions, they are expected to use the rice to test their predictions.

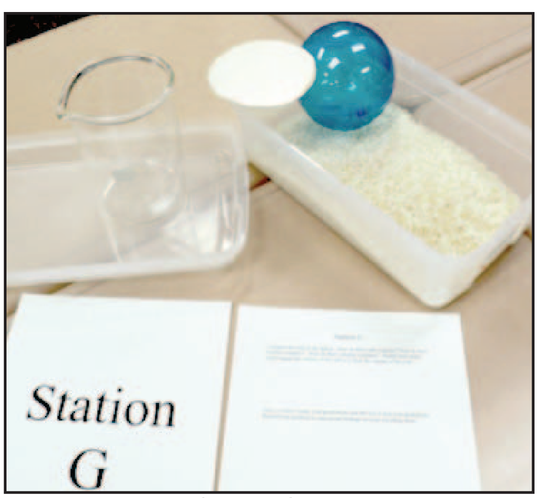

Fig 7 Station G materials

Mathematical Concepts

The mathematical concepts for Station G are: estimation, volume of sphere, volume of cone, radius, and discovery of the volume of the sphere.

Extensions

For advanced students, the surface area of a sphere could be included. For a hands-on approach, peel an orange and place the peels into four circles that have the same radius as the sphere. Students should be able to see that the formula for surface area of a sphere derives from the area of the circle that has the same radius as the sphere.

Notes

This is typically the most difficult station for students to comprehend. The goal is for students to understand that the formula for the volume and surface area of the sphere derives from the fact that four cones that have the same radius as the sphere as well as each height equal to the radius fill up the volume of the sphere. Since it is almost impossible to find commercially-made spheres with a cone of the same radius and height, you will have to make your own cone to fit a sphere that you can open.

Implications

Measurement is tied to ideas and skills in other mathematics standards: number, geometry, algebra, and data analysis. Measurement ideas and skills are also closely related to our daily life, various

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career skills, and other subject areas. As shown by standardized assessment test scores and teachers' reports, middle school students perform at a low level on measurement concepts. To improve these results, students need not only to apply formulas but to have experience with weights, area, perimeter, and volume. By performing at stations, students are better able to attach a numerical value to measurable attributes and to practice and enhance their existing knowledge in measurement. These interactive stations provide students with opportunities to learn and practice measurement concepts and skills. These opportunities provide more in depth understanding than paper and pencil computing alone.

We hope this paper provokes discussion among teachers on how to engage and challenge students' thinking in the classroom; how to encourage students to listen carefully to each other's ideas; how to help students clarify and justify their ideas; how to encourage reasoning and making sense in the classroom; and how to give more ownership of the classroom to students.

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Measurement Stations Record Sheet - Station A

Prediction:
Pick up each object, estimate its weight without using the balance scale. Write the items and their estimated weights on your record sheet in order from lightest to heaviest.

Estimate the weight of each object and list them in order from lightest to heaviest.

	Object	Estimated Weight	Actual Weight
Lightest			
Heaviest			

Actual:
After recording your predicted order, use the balance scale to weigh each object and record the actual weights on your record sheet.

How close were your predictions? What might account for any errors in your predictions?

Measurement Stations Record Sheet - Station B

The Problem:
Two sheets of paper (8.5” by 11”) are rolled up to form cylinders. Imagine there are bases. Think about the volume of each cylinder and make a prediction.

Prediction:
Would the two volumes be equal? Would the short cylinder have the greater volume? Would the tall cylinder have the greater volume?

Explanation:
Why did you predict as you did?

Experiment:
Use the rice to fill the tall cylinder. Then fill the shorter cylinder and compare the two amounts of rice. Was your prediction correct?

Extension:
Use the formula for volume of a cylinder to calculate the volume of each cylinder.
Volume = (radius squared)·(pi)·(height); Circumference = 2·(pi)·(r)

Measurement Stations Record Sheet - Station C

Observe all of the bottles at this station. Predict the volume of each bottle. Then place the bottles in order from least volume to greatest volume. Write your prediction on your record sheet.

Once you have completed the predicted order, use water and the graduated cylinders to find the actual volume of each of the bottles.

Record your prediction of the order of the volume of the bottles from least to greatest. Then use water to find the actual volumes and record your findings.

	Bottle label in order from least to greatest	**Predicted volume (optional)**	**Actual volume**
Least			
Greatest			

How did you do? What might account for any errors in your predictions?

Measurement Stations Record Sheet - Station D

Observe the given figures then predict their relative sizes from smallest area to largest area. Write the figures in order of their area from least to greatest. Record your list in the table on your recording sheet and then use the transparency grid to check your predictions. Put the actual order in the table as well.

	Predicted order of the areas of lettered figures (Least to Greatest Area)	**Actual order of the areas of lettered figures (in square centimeters)**
Least		
Greatest		

How did you do? What might account for any errors in your predictions?

Measurement Stations Record Sheet - Station E

Observe the given figures. Put the figures in order in terms of their perimeter from least to greatest. Record your list in the table on your recording sheet and then use string to check your predictions. Put the actual order in the table as well.

	Predicted order of the perimeters of lettered figures (Least to Greatest Perimeter)	Actual order of the perimeters of lettered figures (in centimeters)
Least		
Greatest		

How did you do? What might account for any errors in your predictions?

Measurement Stations Record Sheet - Station F

Compare the cube to the pyramid. How do the measures of their bases compare? How do the measures of their heights compare? How do their volumes compare? Predict how many times larger the volume of the cube is than the volume of the pyramid.

Compare the cylinder to the cone. How do the measures of their bases compare? How do measures of their heights compare? How do their volumes compare? Predict how many times larger the volume of the cylinder is than the volume of the cone.

Compare the triangular prism to the triangular pyramid. How do measures of their bases compare? How do measures of their heights compare? How do their volumes compare? Predict how many times larger the volume of the prism is than the volume of the pyramid.

Once you have made your predictions, use the rice/water to test your predictions. Record your actual findings.

Shapes	**Base**	**Height**	**Predicted Volume**	**Actual Volume**
Cube				
Square pyramid				
Cylinder				
Cone				
Triangular prism				
Triangular pyramid				

Measurement Stations Record Sheet - Station G

Compare the size of the cone to the size of the sphere (the sphere can be separated into two pieces.) How do their radii compare? How do their heights compare? How do their volumes compare? Predict how many times larger the volume of the sphere is than the volume of the cone.

Once you have made your predictions, use the rice to test your predictions. Record your predictions and actual findings.